The Unusual Minimum of Sunpot Cycle 23

Source

"The unusual minimum of sunspot cycle 23 caused by meridional plasma flow variations"

by

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The Unusual Minimum in Solar Activity

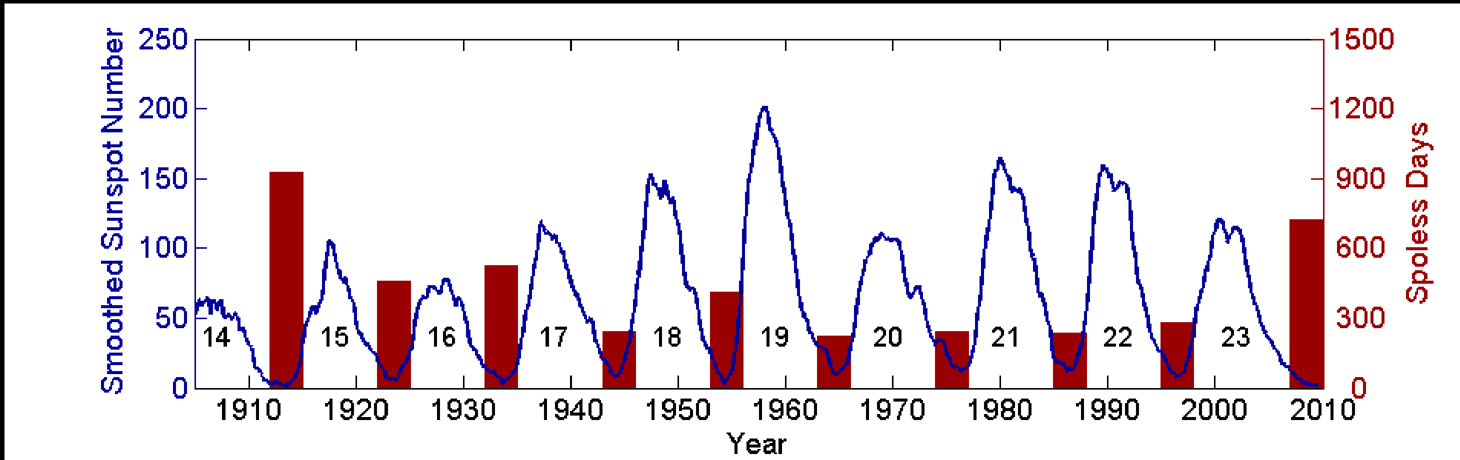


Figure 1: Total number of spotless days between the maxima of solar cycles. One has to go back to cycle 14 for a deeper minimum: Credit: Based on data provided by David Hathaway (NASA-MSFC). Figure from Nandy, Muñoz-Jaramillo & Martens, Nature 3rd March, 2011 issue

- Unusually large number of sunspot-less days

- Very weak solar polar and interplanetary magnetic field

The Spotless Sun at Minimum of Cycle 23

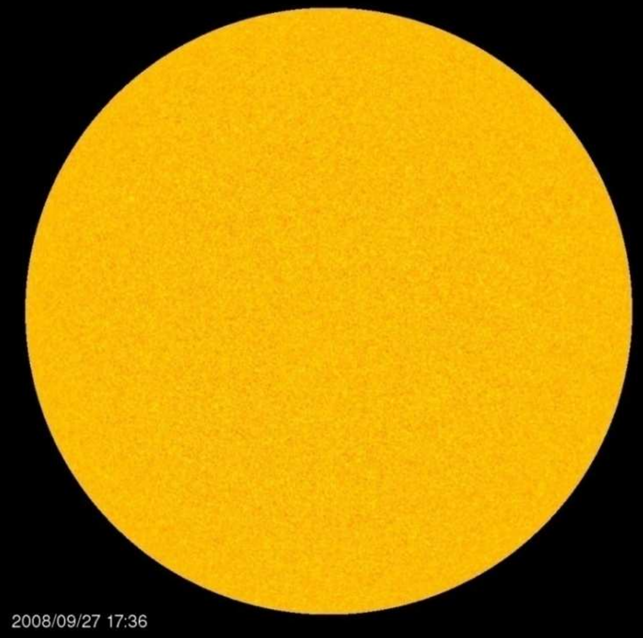
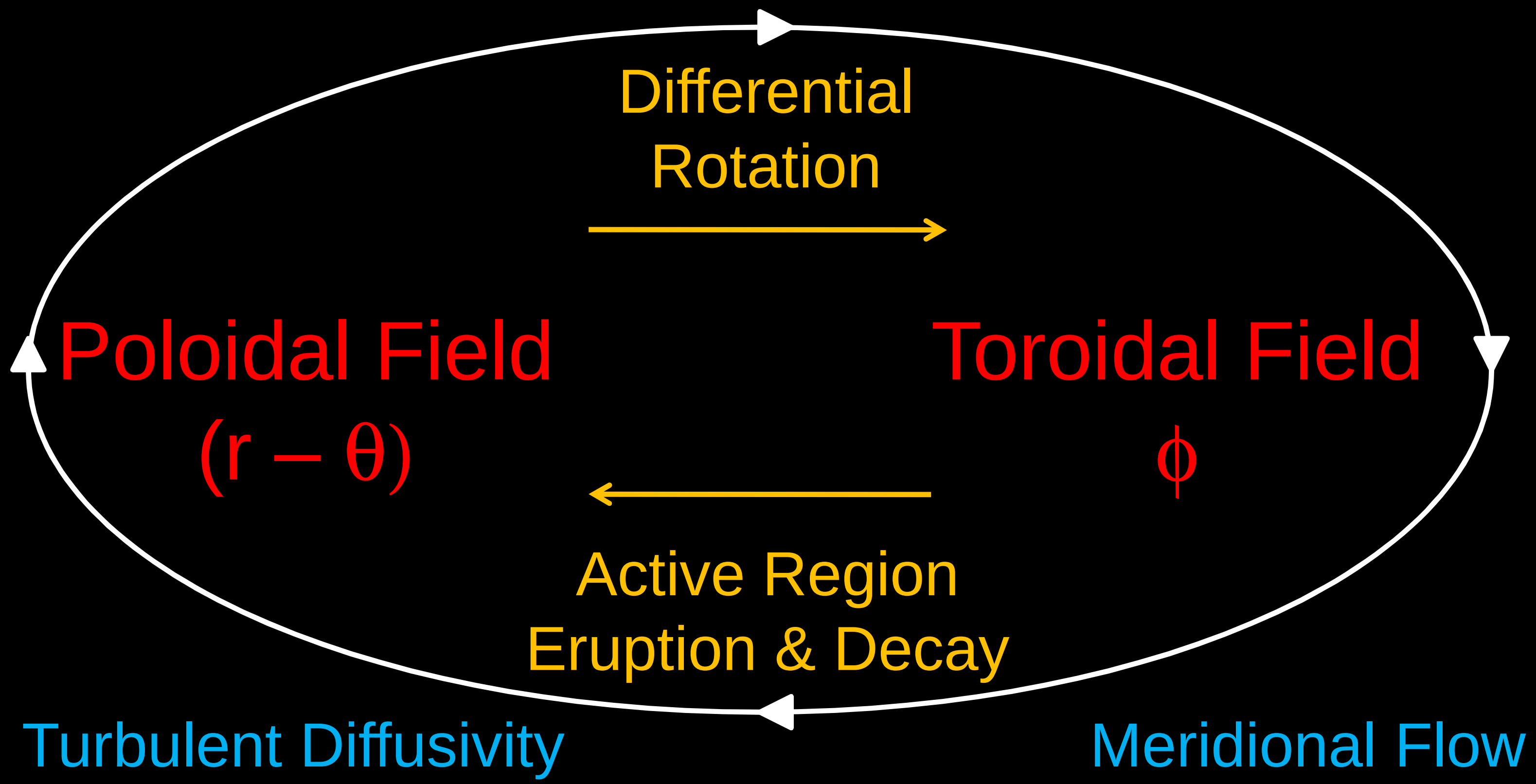


Figure 2: A spotless sun during the minimum of cycle 23. Credit: SOHO/ESA/NASA

- Hardly any solar storms and hence fair space weather; important for planning space missions, estimating mission lifetime and scheduling air-traffic on polar routes

- What caused this unusual lull in activity and can we predict it?

What Produces Sunspots: The Solar Dynamo



Cycle to Cycle Variation

—Differential rotation, diffusivity: Not significant

—Tilt angle: Not significant

—However, meridional circulation is highly variable

Solar Cycle Simulations

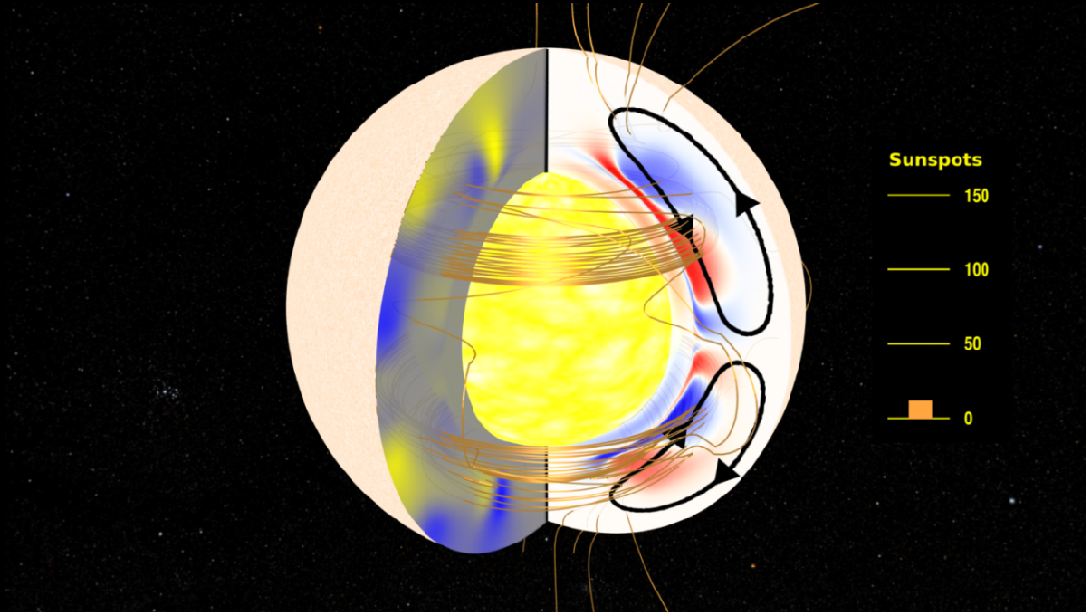


Figure 3: Visualization of the magnetic field (red and blue bands) inside the Sun from a solar dynamo model. The meridional flow of plasma is shown by the black loop with arrows indicating the direction of flow. Credit: William T. Bridgman (NASA-GSFC), Dibyendu Nandy, Andrés Muñoz-Jaramillo & Petrus C.H. Martens

- 210 solar cycles simulated: Results show that a change from a fast meridional flow in the first half of a cycle to a slower flow in the second half reproduces the characteristics of cycle 23 minimum

Theory of a Deep Solar Minimum

- Re-distribution of the magnetic field of dying sunspots by diffusion and meridional circulation first cancels the old polar field and then strengthens the new cycle polar field

- A fast meridional flow carries both positive and negative polarity sunspots towards the pole, less “net” flux – weaker polar field

- A fast flow early in the cycle also allows less time for the creation of strong sunspot forming magnetic fields in the Sun’s interior; the cycle (n) runs out of steam before the start of the following cycle (n+1)

- A subsequent, slower flow distances in time the sunspot forming magnetic field of the following cycle (n+1) from the previous one (cycle n), resulting in a large number of spotless days between them

Summary and Implications

- Our modeling makes a testable prediction; very deep solar cycle minima should be associated with weak large-scale solar dipolar field in the solar system

- Results indicate that solar cycle is fairly robust to reasonable changes in the meridional flow (*producing Maunder-like minima requires either extreme variations or additional physics*)

- Modeling opens up the possibility of predicting deep minima based on observations of *internal* meridional flow profile

- This would help in planning space missions, estimating satellite lifetimes, and scheduling air-traffic on polar routes

Visual

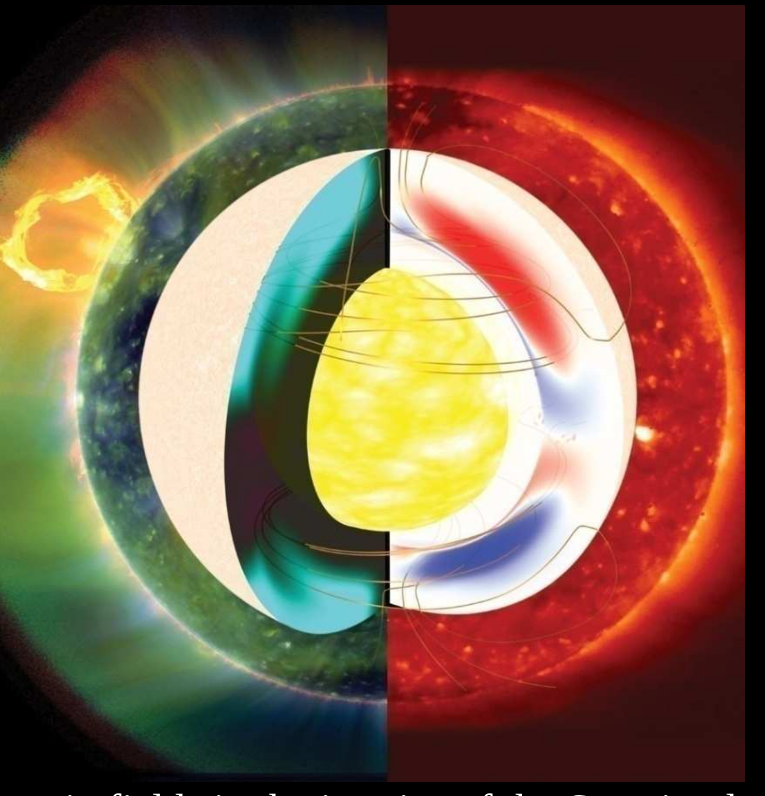


Figure 4: This collage shows magnetic fields in the interior of the Sun simulated using a solar dynamo model (center) and the observed solar corona at two different phases of solar activity: A quiescent phase during the recent, unusually long minimum in solar activity (right) and a comparatively active phase following the minimum (left). Sunspots originate from the internal magnetic field and are the seats of solar storms that generate beautiful auroras but are also hazardous to our space-based technologies. This computer modeling shows that a deep minimum in solar activity occurs when the magnetic field belts of two successive cycles (blue and red colored regions in the right) become separated in space and time due to changes in solar internal meridional plasma flow. This separation of the internal magnetic field belts results in a lack of sunspots eruptions (and solar storms), over a long period of time, between two successive sunspot cycles. Image credit: NASA/Goddard/SDO-AIA/JAXA/Hinode-XRT/Cygnus-Kolkata/; William T. Bridgman, Dibyendu Nandy, Andrés Muñoz-Jaramillo & Petrus C.H. Martens.

Sunspot Cycle Simulation Movies

- Available online at:

http://svs.gsfc.nasa.gov/search/Series/SolarDynamo.html

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